Digging Into Climate Models' Needs with SPADE

Research Highlight

Using their newly designed Separate Physics and Dynamics Experiment (SPADE) methodology, scientists at Pacific Northwest National Laboratory can now isolate resolution-dependent behavior of specific components in climate models. This separation is key to building atmospheric models with multiple resolutions, providing high-resolution information from certain regions, for processes such as rainfall, and lower resolution information elsewhere. To build such models, scientists need to understand how the behavior of each physics-based component changes at different resolutions, and then how that influences the whole model.

"Determining the resolution requirements inside a model is difficult because of the connections between many of the model's components," said Dr. William Gustafson, Jr., Pacific Northwest National Laboratory (PNNL) atmospheric scientist and first author on the study. "With SPADE, we can examine the resolution behavior in a more isolated way."

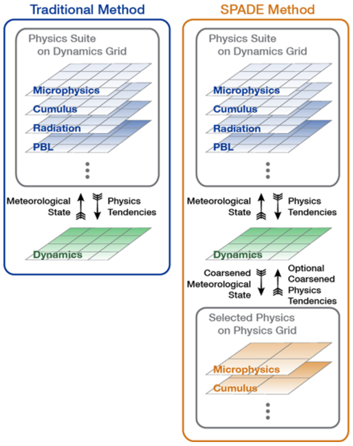
The team built the SPADE infrastructure by adapting the WRF model to use an alternate grid, simulating selected physics components at high and low resolution at the same time. The size of the grid cell used by the model determines the resolution of the model. For example, in climate models, interactions such as rainfall are often simulated using grid cells that are 100 kilometers, or 62 miles, across. In more detailed models, the cells are much smaller. Scenarios using the more detailed models take much longer to run.

The team used a model domain that covered the central United States for a time period coinciding with the U.S. Department of Energy's Midlatitude Continental Convective Clouds field campaign, which ran from April through May 2011 (http://campaign.arm.gov/mc3e/). Using this data and a selection of model simulations with different resolutions, they systematically analyzed selected cloud behaviors for a range of grid spacings. With the data generated, they analyzed the probability distributions of liquid cloud amounts to understand the microphysics behavior at each grid spacing. Microphysics is the physics component of the model that handles the inside of clouds at the smallest scales. It includes processes such as cloud droplet formation, the freezing of snowflakes, and what happens when snow, rain, and cloud droplets collide with each other.

Using the SPADE methodology, the team was the first to document the newly ported Community Atmosphere Model Version 5 (CAM5) physics suite, which was recently added to the WRF model by researchers at PNNL. The team studied the Morrison microphysics from WRF and the Morrison-Gettelman microphysics from the Community Atmosphere Model v5 (CAM5) for grid spacings anticipated to be used in the next 5 to 10 years. These grid spacings span the cloud modeling gray zone, where the model grid partially resolves cloud processes.

They found that the Morrison microphysics scheme in WRF has stronger resolution dependence than the Morrison-Gettelman scheme in CAM5. They demonstrated that while the ability to represent partial cloud fraction in Morrison-Gettelman improves the resolution independence by allowing clouds to form before the whole grid cell becomes saturated, it is not the primary reason for the reduced resolution dependence in this scheme.

To accurately predict how energy supplies and use would alter crop abundance, water availability, and air quality, scientists run climate simulations. To get these predictions faster and at less cost, scientists are designing models that operate at a low resolution in some areas to save computer resources for higher resolution in other parts of the world where detail is most needed. While the mathematics for dynamics, essentially the movement of air, using multiresolution models is feasible, physics-based processes, such as cloud formation, are more difficult in multiresolution



SPADE's methodology complements a traditional workflow for identifying resolution dependence by isolating specific model components using a multi-grid approach.

models. Scientists need to understand how the physics components interact at different resolutions. The SPADE methodology helps provide this information, and the resulting knowledge will help them develop physics capabilities in variable resolution models.

From a scientific perspective, SPADE provides a new testbed capability in a regional weather model that can mimic the behavior of global climate models. Specifically, they embedded the SPADE capability into the Weather Research and Forecasting (WRF, http://www.wrf-model.org/index.php) model, a popular regional weather model used around the world. By using WRF, testing the physics will be cheaper and will allow scientists to understand their new physics parameterizations before fully implementing them in a global climate model.

Reference(s)

Gustafson WI, PL Ma, H Xiao, B Singh, PJ Rasch, and JD Fast. 2013. "The separate physics and dynamics experiment (SPADE) framework for determining resolution awareness: A case study of microphysics." Journal of Geophysical Research – Atmospheres, 118(16), doi:10.1002/jgrd.50711.

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Cloud Life Cycle